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NATIONAL ASTRONOMICAL OBSERVATORIES
CHINESE ACADEMY OF SCIENCES

Triple Flares of AT 2021aeuk within Five Years in the Active Galaxy SDSS J161259.83+421940.3

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BIZARRE FLARES in OPTICAL

- ✓ Long-lived, large-energy-released
- ✓ Recurring bumps / flares
- ✓ Bowen fluorescence lines
- ✓ Lower brightness than the pre-flare state
- Etc ...



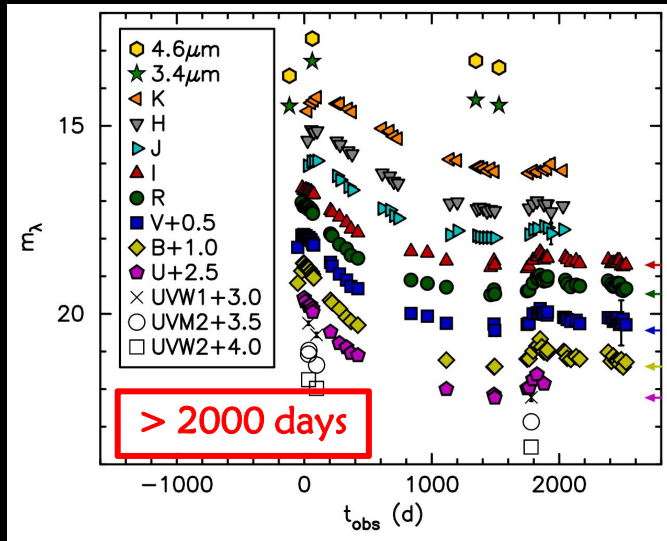
□ Progenitor ?

TDE
Supernova
AGN accretion
etc ...

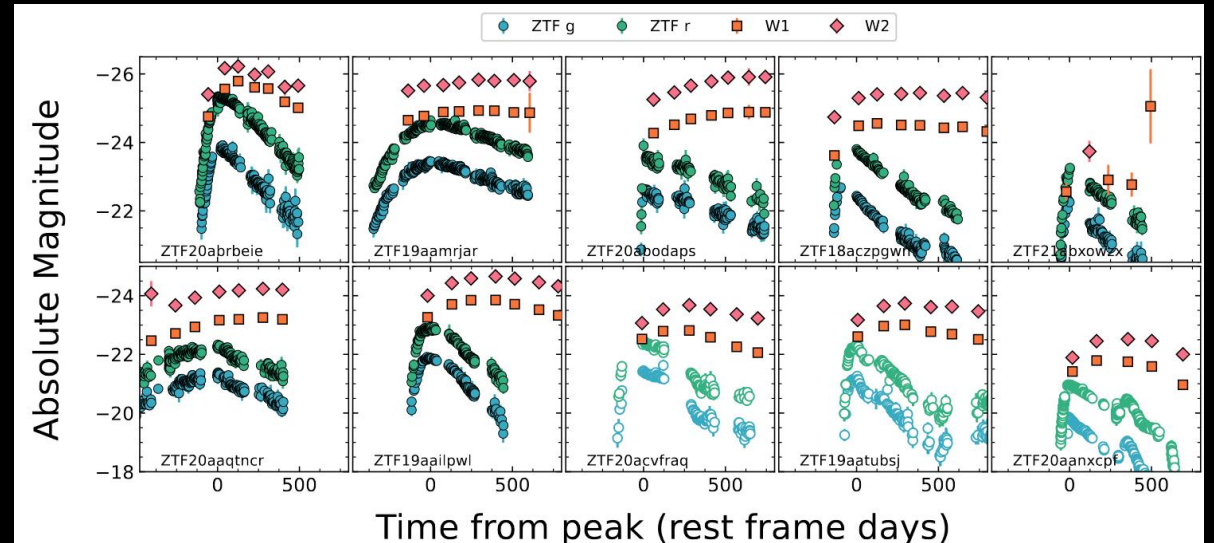
□ Environment ?

AGN involved
High stellar density
Dusty surroundings
etc ...

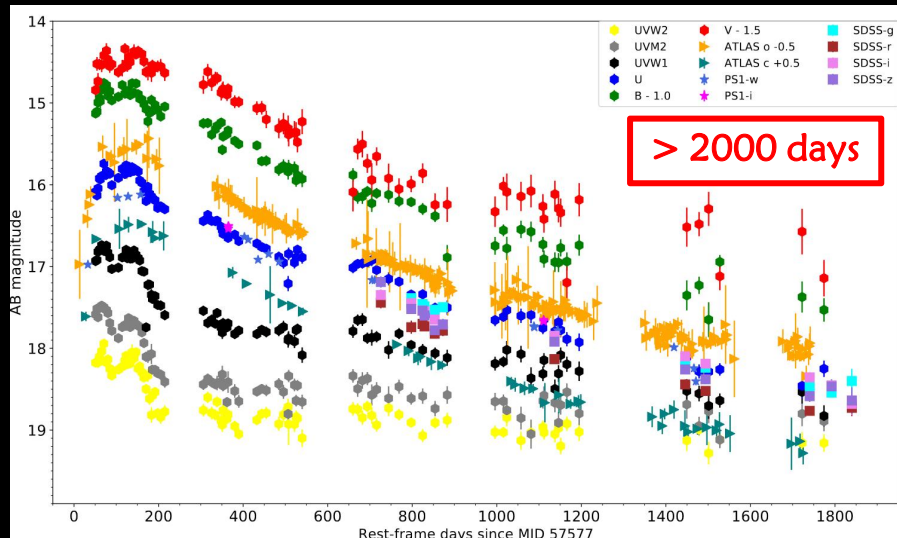
Atypical Light Curves — Long-lived, large-energy-released



(pTDE candidate, PS1-10adi, Kankare P. et al. 2017)



(Wiseman P. et al. 2024)



(TDE candidate, PS1dtm, Petrushevska T. et al. 2023)

AGN accretion coupled with:

Supernova

(Holoien T. et al. 2022)

Massive star disruption

(Wiseman et al. 2023)

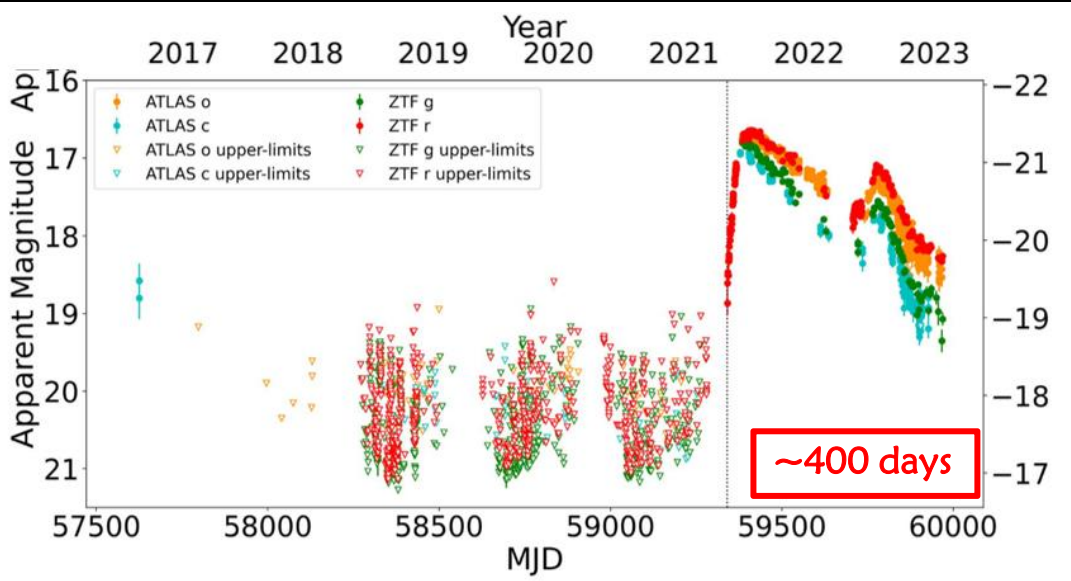
Dense cloud accretion

(Lin et al. 2023)

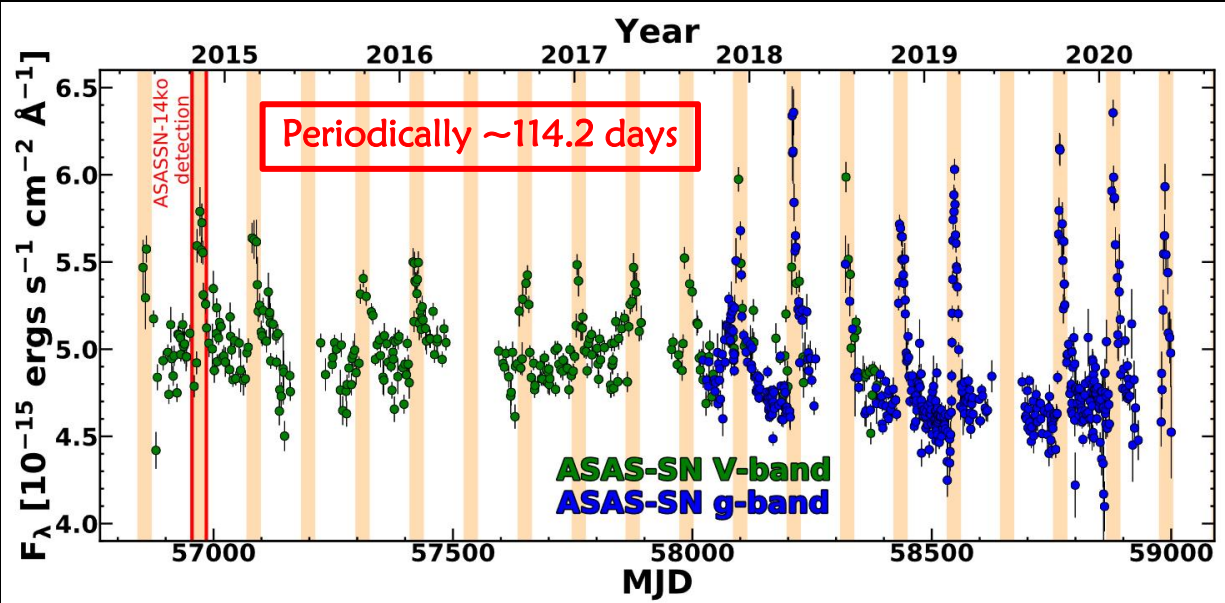
Superluminous supernova in the nuclear region

Etc ...

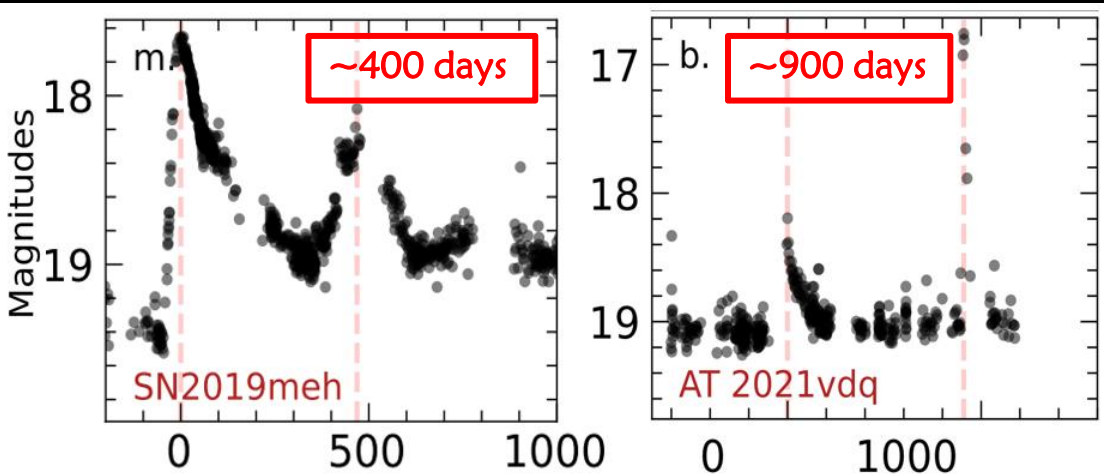
Atypical Light Curves ——— Bumps / Recurring flares



(BFF candidate, AT 2021loi, Makrygianni L. et al. 2023)



(pTDE, ASASSN-14ko, Payne V. et al. 2021)



SLSNe-II candidate
(Soraisam M. et al. 2022)

pTDE cadidate
(Somalwar J.J. et al. 2023)

Late-time formed accretion disk during TDE

(Guo H. et al. 2023)

Shock interaction with CSM

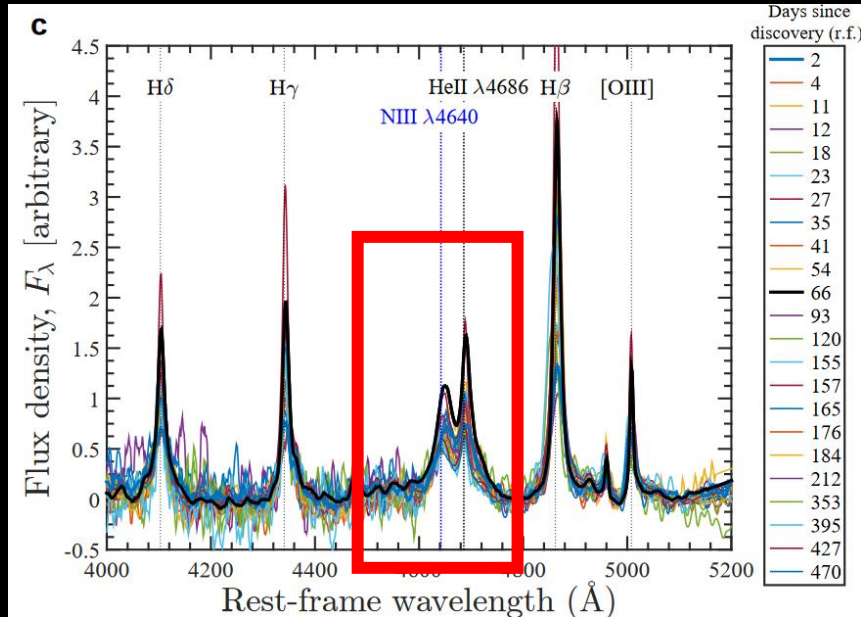
(Hosseinzadeh G. et al. 2022; ...)

Partial TDE

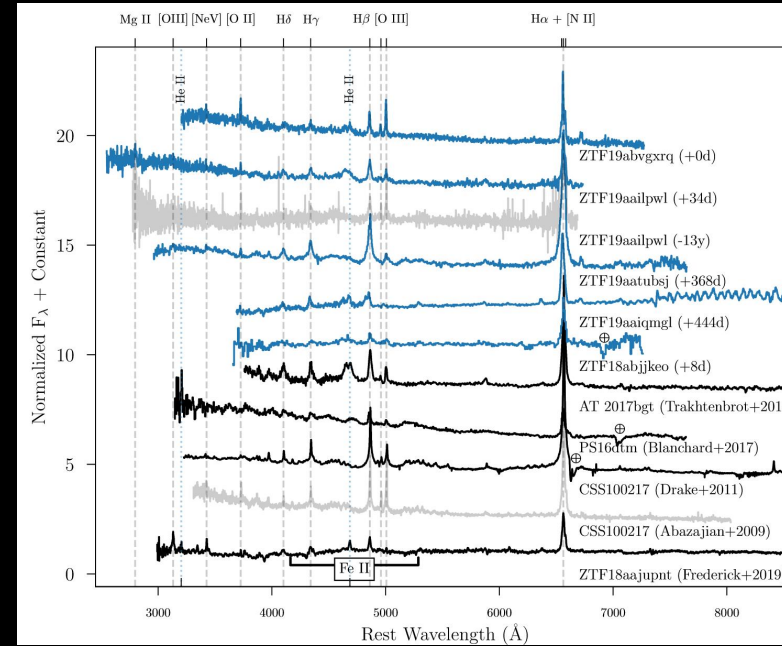
(Guillochon J. & Ramirez-Ruiz E. 2013; ...)

Etc ...

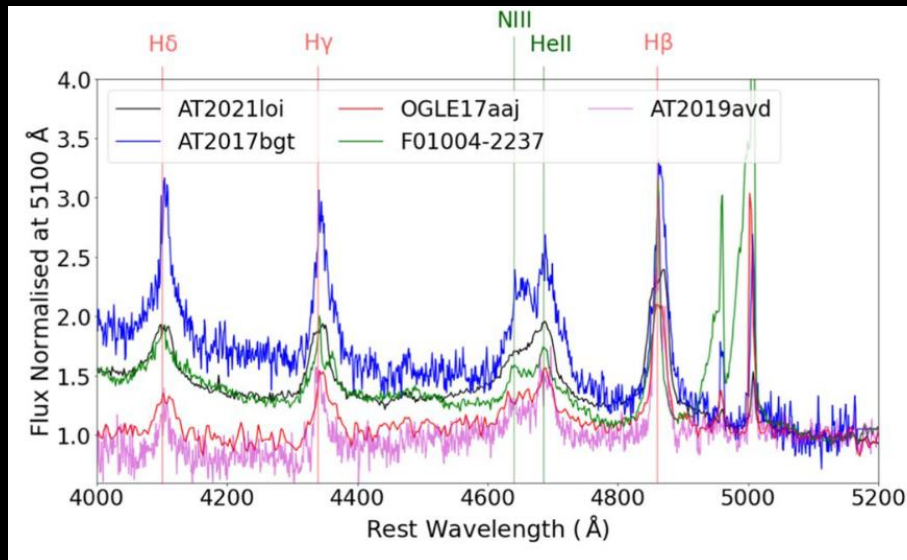
Atypical On-burst Spectra — Bowen fluorescence lines



(Trakhtenbrot B. et al. 2019)



(Frederick S. et al. 2021)



(Makrygianni L. et al. 2023)

➤ Intense UV emitters

➤ Abnormal local metallicity

Enhancement/re-ignition of AGN accretion

(Trakhtenbrot B. et al. 2019)

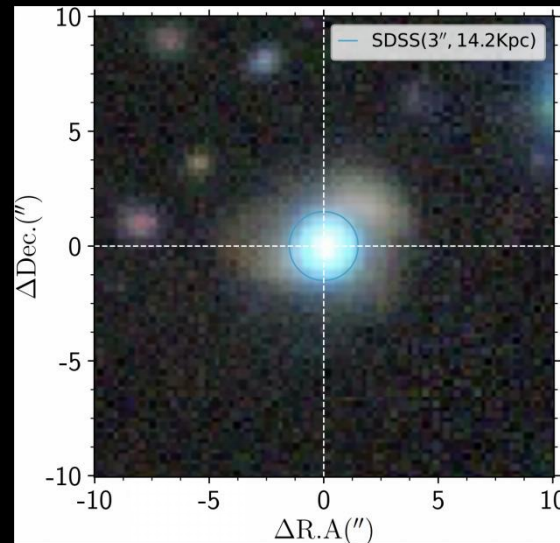
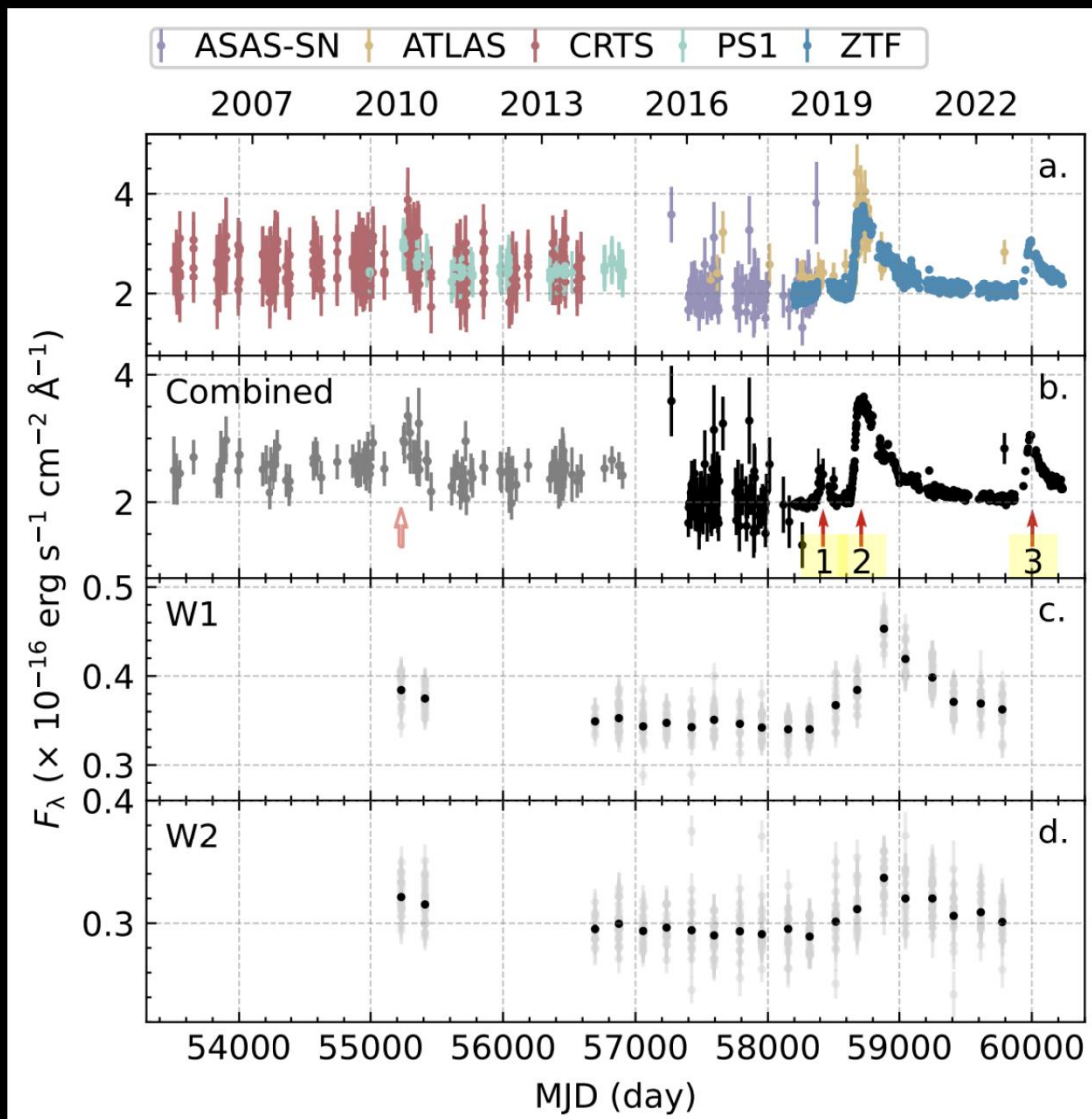
Existence of Wolf-Rayet Star

(Crowther P. A. et al. 2007; ...)

TDE of Star going CNO cycle

(Kochanek C.S. et al. 2016; ...)

AT 2021aeuk



SDSS J161259.83+421940.3

NLSy1

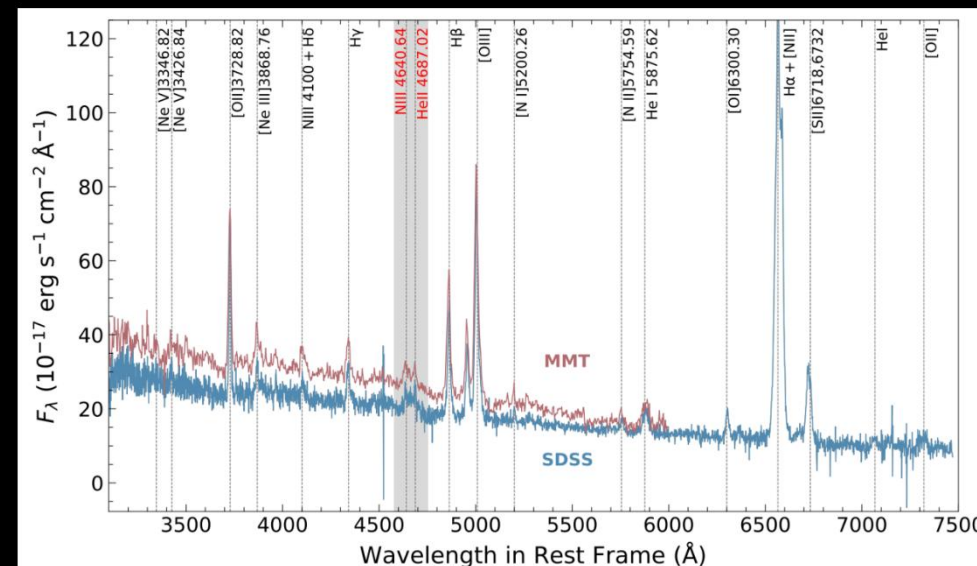
Redshift ~ 0.23366

Radio-loud ($\text{Log } R^* \sim 1.06$)

$W1-W2 \sim 1.1$

Irregular morphology

(Subaru/HSC, Aihara et al. 2022)

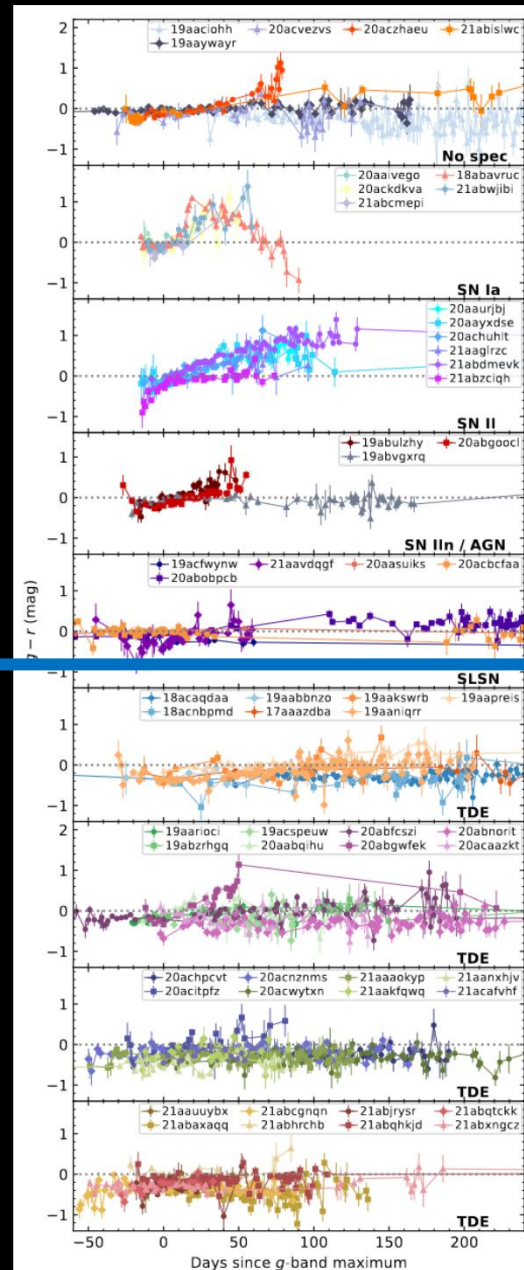
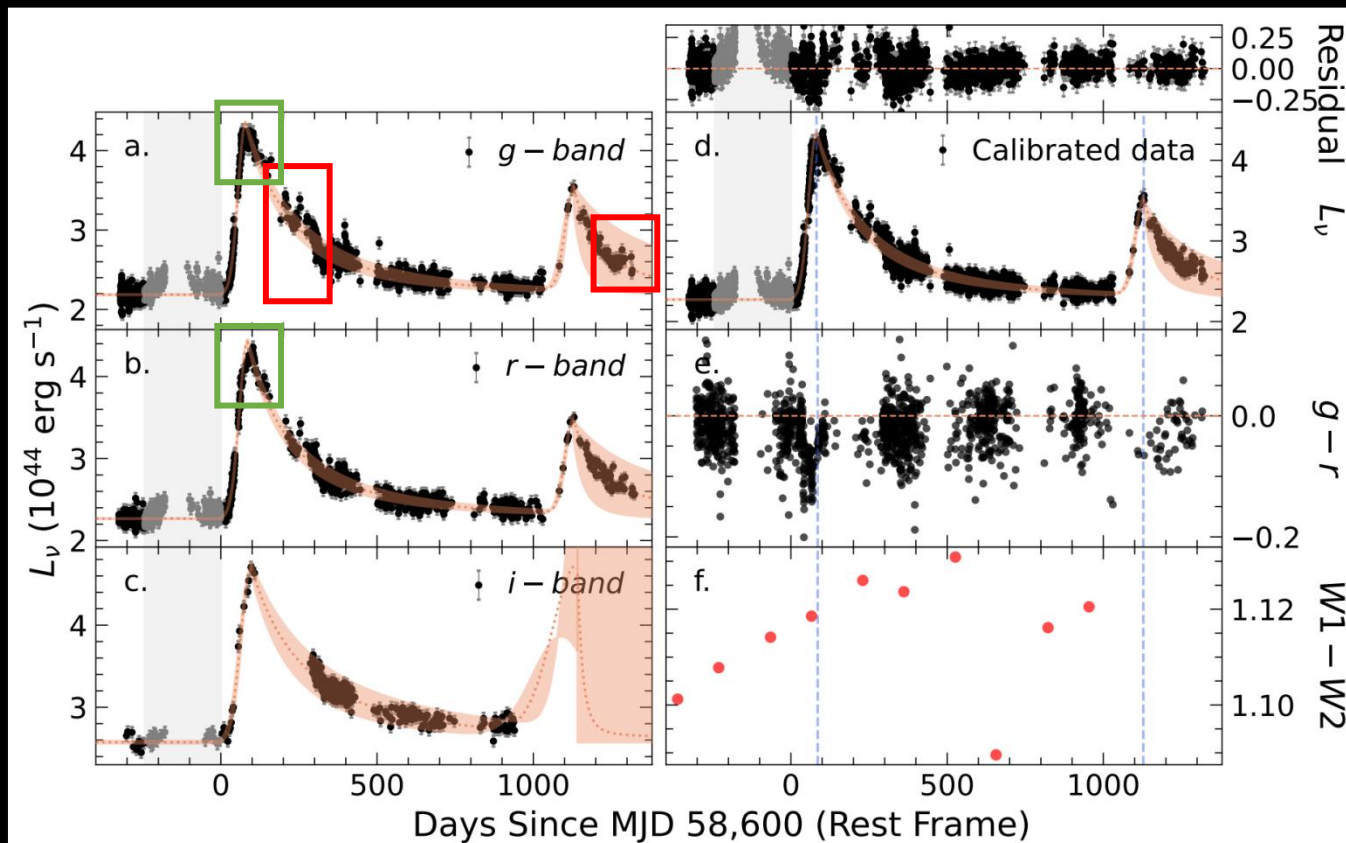


**Pre-burst
Spectra**

Long-lasting metallicity enhancement

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Light Curve Overview

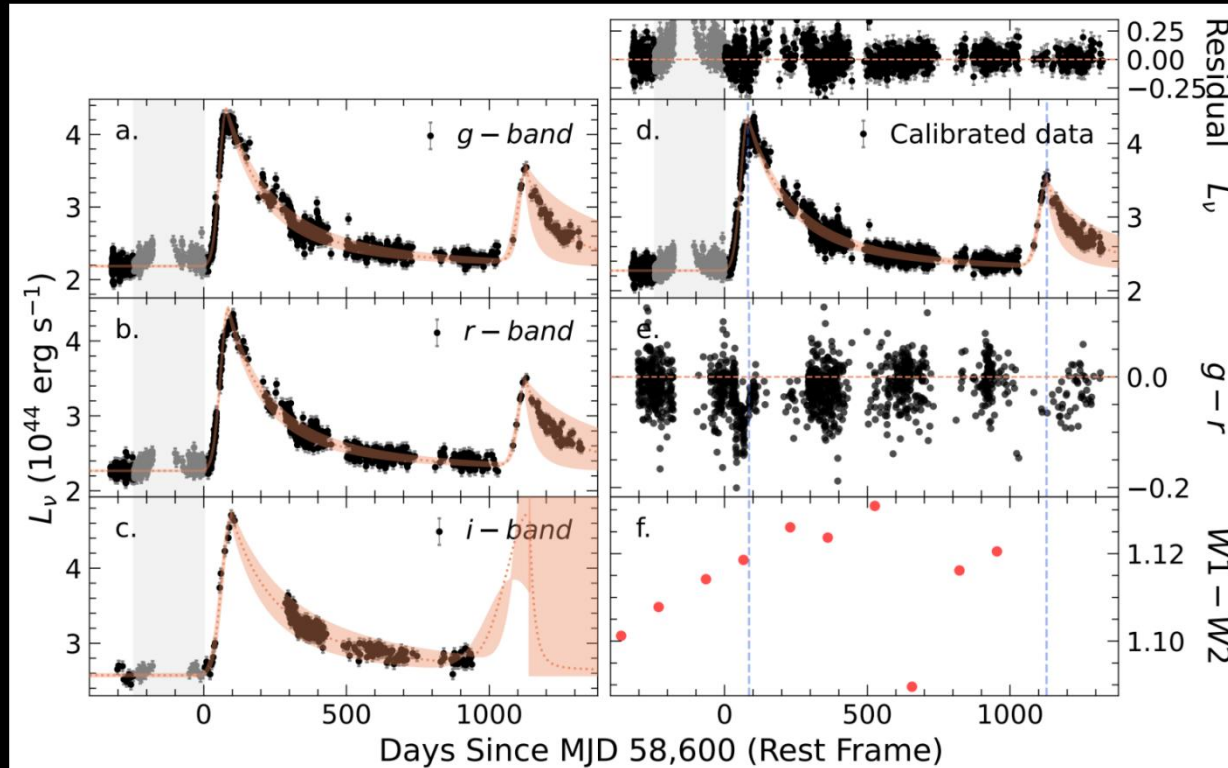


- ✓ Fast rise, long-term decay (>1000 days)
- ✓ Minor difference of peaks in *g*-, *r*-band
- ✓ Prominent bumps on decay phase
- ✓ Blue *g-r* color, and minor evolution later

Resemble to
TDE evolution?

(Yao Y.H. et al. 2023)

Light Curve Fitting



Gaussian + Power Law

$$L_{\nu}(t) = L_{\nu}^{\text{peak}} \times \begin{cases} e^{-(t-t_{\text{peak}})^2/2\sigma^2} & t \leq t_{\text{peak}} \\ \left(\frac{t-t_{\text{peak}}+t_0}{t_0}\right)^p & t > t_{\text{peak}} \end{cases}$$

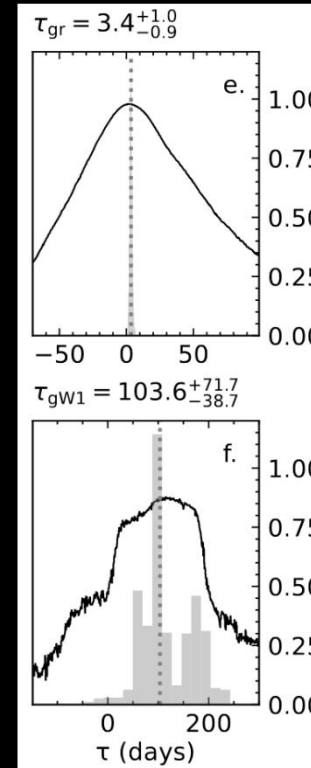
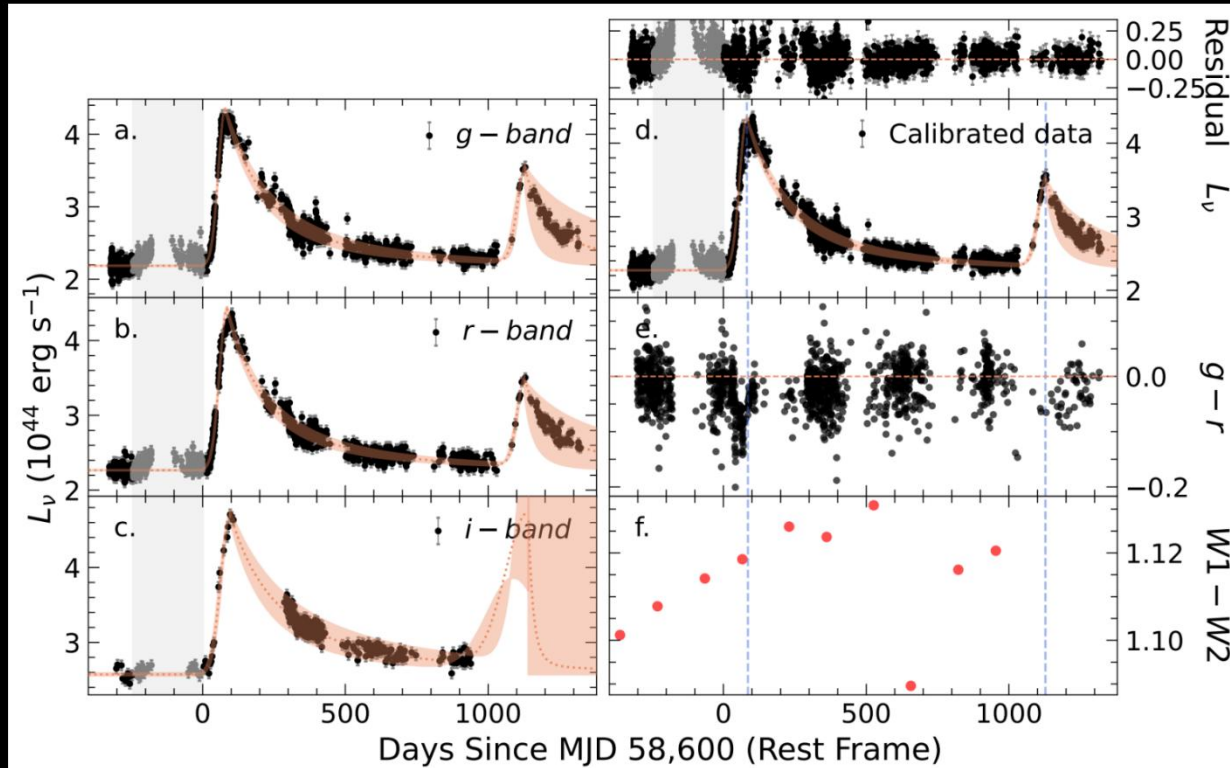
Fittings for Flare II and Flare III

$$L_{\nu}(t) = L_{\nu,0} + \begin{cases} L'_{\nu,\text{rise}}(t) & t \leq t'_{\text{peak}} \\ L'_{\nu,\text{fall}}(t) + L''_{\nu,\text{rise}}(t) & t'_{\text{peak}} < t \leq t''_{\text{peak}} \\ L'_{\nu,\text{fall}}(t) + L''_{\nu,\text{fall}}(t) & t > t''_{\text{peak}} \end{cases}$$

$$p = \begin{cases} -2.99^{+0.13}_{-0.14} & \text{Flare II} \\ -1.61^{+0.34}_{-0.65} & \text{Flare III} \end{cases}$$

Deviate from TDE prediction index - $\frac{5}{3}$?
(Great degeneracy between p and t_0)

Time Lag Analysis



Continuum Reverberation Mapping:

$$\tau_{g-r} = 3.4^{+1.0}_{-0.9} \text{ days}$$

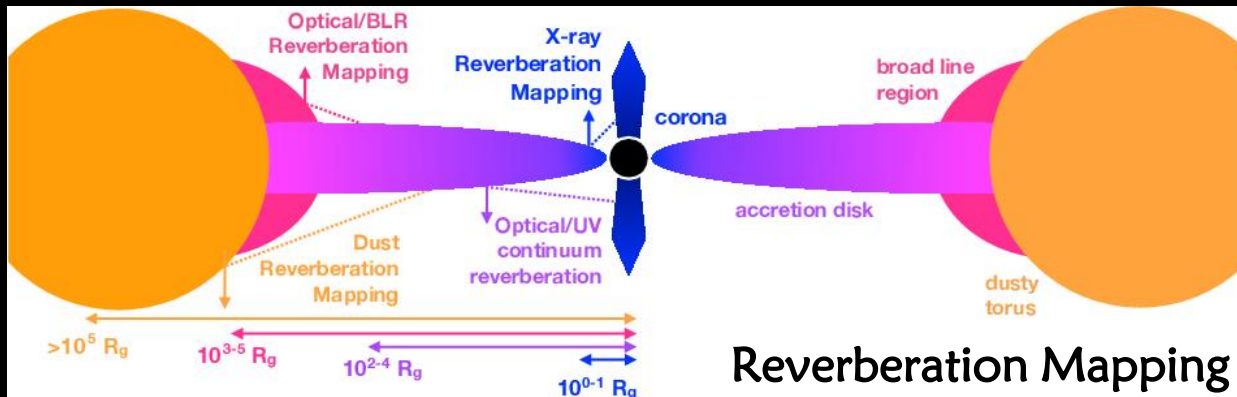
12 times larger than the SSD prediction



Unlike typical AGN radiation

Dust Reverberation Mapping:

$$\tau_{g-w1} = 103.6^{+71.7}_{-38.7} \text{ days}$$



Reverberation Mapping

(Cackett E. et al. 2021)

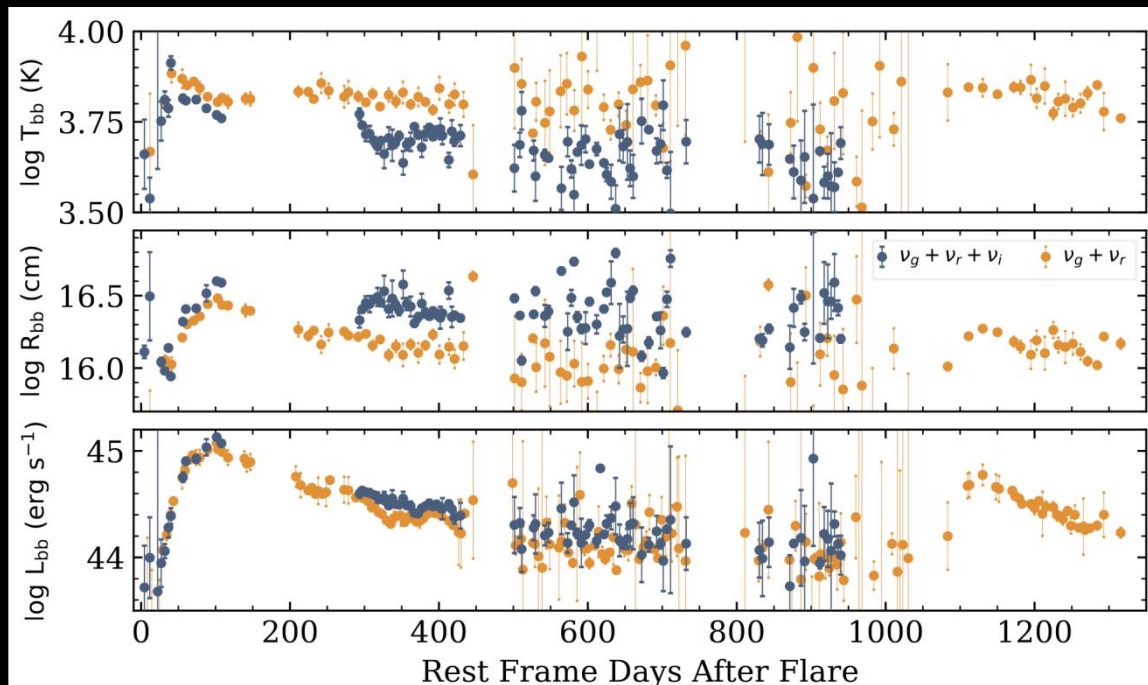
WISE
Sampling
Deficiency ...

Generally smaller than 325 days
derived from $R-L$ relationship
(Lyu et al. 2019, Chen Y.-J. et al. 2023)



The UV/optical emitter may locate
between accretion disk and torus

Blackbody Fitting

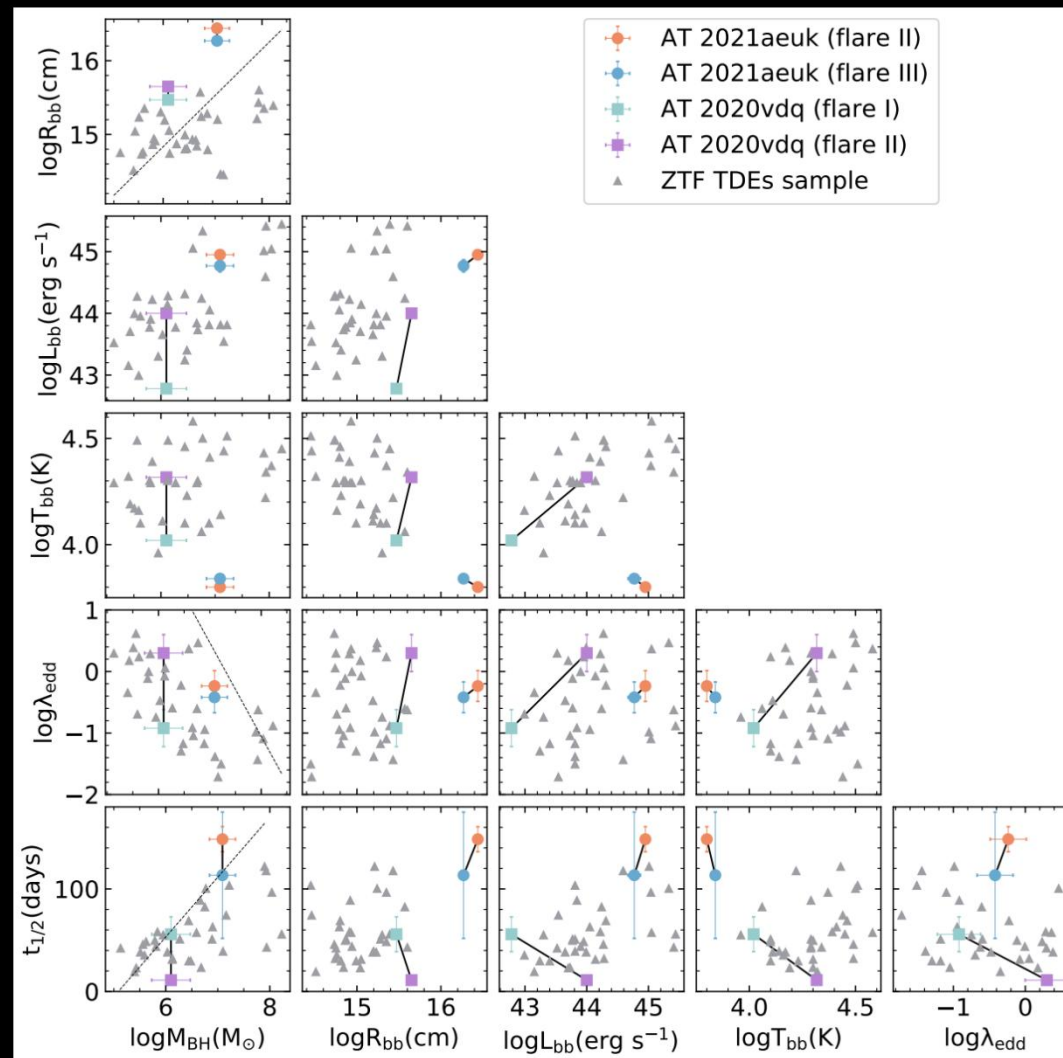


Lack of UV photometry leads to the inaccuracy

Minor after-peak temperature evolution

Lower BB temperature $\sim 10^{3.8}$ K

Larger BB radius and luminosity



Summary

- ✓ Triple flares occurred within 5 years in an active galaxy
- ✓ Pre-burst spectra exhibited Bowen fluorescence lines
- ✓ Flares show fast rise and long-term decay (> 1000 days), with recurring bumps during decay phase
- ✓ Blue g-r color and minor after-peak evolution
- ✓ $\tau_{g-r} = 3.4^{+1.0}_{-0.9}$ days larger than SSD prediction
- ✓ $\tau_{g-W1} = 103.6^{+71.7}_{-38.7}$ days smaller than R-L prediction
- ✓ Power-law decay index are $-2.99^{+0.13}_{-0.14}$ and $1.61^{+0.34}_{-0.65}$
- ✓ Low Blackbody temperature $\sim 10^{3.8}$ K with minor after-peak evolution
- ✓ Larger BB radius and luminosity than TDE sample



(From Zelda)

Unlikely to be driven by single physical origins, but transients (TDE / SN) coupled with accretion disk ?



Are the heads related or independent ?

What is the habitat ?

Thank you for listening !